Advances in emulsion-based (ECC) detectors data analysis and reconstruction techniques

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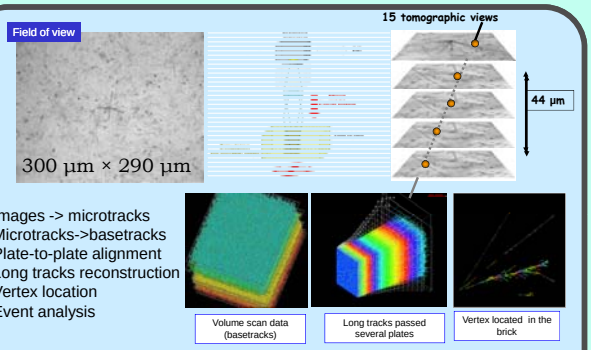
- **Advantages of nuclear emulsion tracker:**
  - unique submicron precision
  - truly 3-dimensional information
  - no high voltage required
  - easy to transport
- **Disadvantages:**
  - difficult to read-out (improved with the automated scanning systems development)
  - no time-stamp – all tracks collected during the emulsion life superimpose
  - sensitive to the elevated temperatures (>27 C)
- **Main Applications:**
  - neutrino physics (OPERA),
  - cosmic rays (suitable to balloons)
  - Muon Radiography
  - Dark Matter (WIMP) research

Automation and image processing technology gives a new life to one of the most historical particles detector

Automated scanning systems with computer-driven microscope and equipped with digital camera – the approach first applied in Nagoya Emulsion group in Japan (idea in 1974). Since 1994 Italian groups join to the automatic scanning development. In 2004 the first prototype of the European Scanning System (ESS) developed for OPERA scanning was operating in Naples. About 32 ESS were constructed and works now in European labs. The additional R&D is ongoing for increase of the scanning power (continuous motion and HW upgrade) and bring it to 50-100 cm^2/h (factor 2-4 in respect to standard ESS).

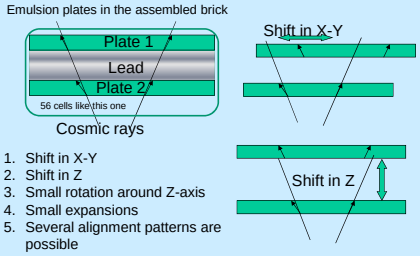
The sequence of tomographic images of the emulsion layer followed by 3-dim segment (microtrack) reconstruction. The microtracks is the basic information coming from the on-line scanning system for the following event reconstruction



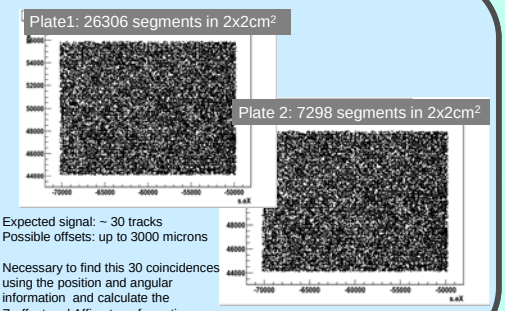
- Images -> microtracks
- Microtracks->basetracks
- Plate-to-plate alignment
- Long tracks reconstruction
- Vertex location
- Event analysis

Starting from the 3-d space segment (microtrack) the reconstruction process in ECC pass the following steps: alignment, long tracks reconstruction, vertex reconstruction and event analysis. Tracking and vertexing are similar to ones used in other 3-d vertex detectors. Alignment is the procedure specific for the emulsions and consists in the search of the matched tracks patterns in the consecutive emulsion plates. Without the time stamp the patterns matching is the only way to separate tracks accumulated after the detector assembling from the transportation tracks and from other background types.

Illustration of the alignment problem:



1. Shift in X-Y
2. Shift in Z
3. Small rotation around Z-axis
4. Small expansions
5. Several alignment patterns are possible

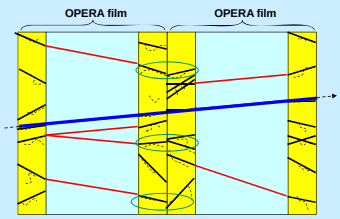


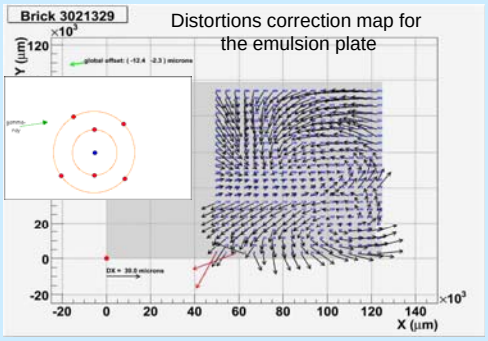
Expected signal: ~ 30 tracks
Possible offsets: up to 3000 microns

Necessary to find this 30 coincidences using the position and angular information and calculate the Z-offset and Affine transformations between 2 patterns

Emulsion deformations and the Compton alignment for Changeable Sheets Doublets

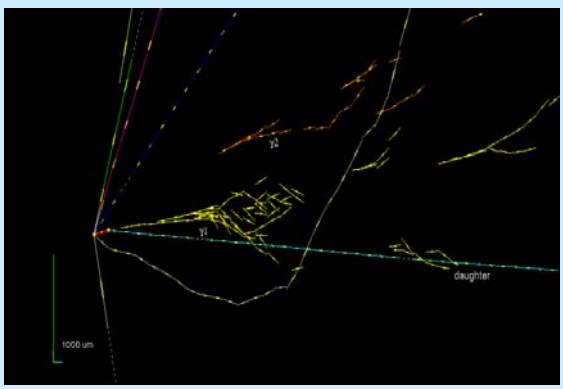
In 1 year of exposure in Gran Sasso about 10/mm² Compton tracks accumulates





The better the alignment accuracy - the higher background rejection power

We can use the natural radioactivity to improve plate-to-plate positioning accuracy!



OPERA Candidate to the τ 1-prong hadron decay mode

- invariant mass of γ-rays 1 and 2:
  120 ± 20 (stat)± 35(syst) MeV/c²
  supporting the hypothesis $\pi^0 \rightarrow \gamma\gamma$
- assuming the charged decay product as π^-, the invariant mass of π^- and 2 gammas: **640** $^{+125}_{-80}$ $^{+100}_{-90}$ **MeV/c²**
  compatible with the ρ(770) mass

With ECC it is possible to obtain a very precise and complete physics information about the reconstructed event:

- Precise event topology reconstruction with submicron accuracy including short decays and kinks research
- Particles identification using dE/dX and multiple scattering information
- Particles momentum reconstruction using the Multiple Coulomb Scattering
- Electromagnetic showers reconstruction